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PERFORMANCE COMPARISONS FOR TWO VERSIONS
OF THE STANIFORTH-MITCHELL BAROTROPIC
NUMERICAL WEATHER PREDICTION CODE

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In a previous report R. E. Newton proposed two improvements to the Staniforth-Mitchell barotropic numerical weather prediction code. Reported here are results of performance comparisons between the original code and an amended version which incorporates the two improvements: a new solution routine for the eigenproblems and a direct solution of the Helmholtz equation. It is found that the proposed improvements do reduce the computation time, but that the new eigenproblem algorithm results in excessive round-off error when single-precision arithmetic is used.

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# PERFORMANCE COMPARISONS FOR TWO VERSIONS OF THE STANIFORTH-MITCHELL BAROTROPIC NUMERICAL WEATHER PREDICTION CODE

## Introduction

Reference 1 proposed improvements to the Staniforth-Mitchell (Ref. 2) barotropic finite element code. It was anticipated that these improvements would effect significant reductions in computation time. Reported here are comparisons of calculated results and times required to perform key sets of calculations using the "original" code with corresponding times for an "amended" code which incorporates the proposed changes. The test problem uses a periodic East-West boundary condition, walls on the North and South boundaries, and a 12x13 grid. Timing data were obtained using an IBM 4381-M1 processor operating in the batch mode. (It was found that the system utility routines SETIME and GETIME do not give useful results when used in the time-sharing mode.)

## Timing Results

<u>Eigenproblem.</u> The first comparison is for the determination of eigenvalues and eigenvectors for the x-direction "stiffness" and "mass" matrices. In the original program the relevant routines are MTRXC and EIGEN2, both called in EBVSET. In the amended version the routines are SETABX, SETD2N, and PEREIG, all called by SETUP. Within PEREIG there are 3 calls to EIGVCP and 2 calls to RAYLYP. The time for the original version is 104 milliseconds and for the amended version is 34 milliseconds. Because the eigenproblem is solved 4 times in the original program and only 3 times in the amended version, the overall comparison is between 415 milliseconds and 101 milliseconds.

Time Step. For each time step the Helmholtz equation is solved once. In the original version an iterative scheme devised by Concus and Golub is used, whereas the amended version uses a direct solution. When only a single iteration is employed in the original version, the difference in solution times is entirely a result of the extensive rearrangement of the right-hand side of the Helmholtz equation that occurs in the Concus and Golub scheme. This rearrangement is effected in SOLHEL. It is believed that the most useful comparison is between the times required for a single execution of the routine TSTEP. For the original version this time is 372 milliseconds and for the amended version it is 331 milliseconds - a saving of 11%.

Remarks

In producing a version of the barotropic code incorporating the changes proposed in Ref. 1 it was discovered that calculated results diverged from those of the original version. It was not immediately obvious which results were better. The likely cause seemed to be differences between the two solutions to the eigenproblem. A comparison was made by constructing the product of the back-transformation matrix with the forward transformation matrix for each version. Since this product should yield the identity matrix, measures of the quality of the transforms were obtained by finding the standard deviation (from unity) for the elements of the principal diagonal and the standard deviation (from zero) for the off-diagonal elements. For the diagonal elements the magnitude for the original version was 3.5E-06 and for the amended version it was 5E-06. For the off-diagonal elements the disparity was greater: 5E-07 for the original and 25E-07 for the amended version.

Since the eigensolution of the amended version is iteratively improved by successive calls to RAYLYP and EIGVCP, efforts were made to improve results by additional calls to this pair of subroutines. Although this did result in addition of one cycle beyond the single cycle recommended in Ref. 1, no further improvement seems to be possible using single-precision arithmetic.

In order to resolve doubts concerning the eigensolution scheme of the amended version, a separate double-precision program was written to compare the eigenvectors and eigenvalues with exact results. Using 3 cycles of improvement, both eigenvectors and eigenvalues were accurate to 15 decimal digits.

## Conclusions

In Ref. 1 attention was directed to the marginal accuracy of single-precision arithmetic for this program. The present study seems to have encountered further evidence in support of this observation. Although the amended version shows some reduction in computation time, its adoption cannot be recommended without first verifying, by use of double-precision arithmetic, that it does indeed give results compatible with those of the original version.

While the present study was proceeding, a new possibility for major improvement in computational efficiency came to attention. In Ref. 3 Temperton and Staniforth describe a new time integration algorithm which they call semi-Lagrangian, semi-implicit. They show that it allows much longer time steps than the present scheme while still giving equal accuracy. Serious consideration should be given to incorporating the new algorithm in the barotropic program.

## List of References

1. Newton, R. E., "Improvements to the Staniforth-Mitchell Barotropic Numerical Weather Prediction Code," NPS69-86-008, Naval Postgraduate School, October 1986.

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3. Temperton, Clive, and Andrew Staniforth, "An Efficient Two-Time-Level Semi-Lagrangian Semi-Implicit Integration Scheme," Q. J. R. Meteorol. Soc., v. 113, pp. 1025-1039, 1987.

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